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TECTONIC ANALYSIS OF BAJA CALIFORNIA AND PARRAS SHEAR BELT IN MEXICO

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SUMMARY OF SIGNIFICANT RESULTS:

1. Geological correlation of terrain across the Gulf of California using ERTS-1 imagery revealed significant similarities between Isla Tiburon, Isla Angel de la Guarda and the San Carlos Range in mainland Mexico. These data were used to reconstruct the position of the Baja Peninsula in Middle Tertiary in two different models. According to our first model Isla Tiburon, Isla Angel de la Guarda and Baja were offset northwestward from their initial positions distances on the order of 140 km, 270 km, and 380 km respectively. After studying this first model in more detail, it seemed almost impossible that Isla Tiburon had moved very far from its present position. Assuming that Isla Tiburon is locked in its position with the Mexican mainland, a second model was developed. The second model locked Isla Tiburon to the Mexican mainland and Isla Angel de la Guarda to the Baja Peninsula. According to this model, Baja and Isla Angel de la Guarda were offset about 230 km. NW from their original positions. Although we fixed Isla Angel de la Guarda in its present position with respect to Baja, it is very probable that it is not locked to Baja but has moved separately. It is uncertain, however, where it originated from so we placed it in a locked position with Baja for the time being. We have found in the second model that such reconstruction brings the isolated mass of Lower Cenozoic intrusives - now lying southeast of Laguna Salada at the head of the Gulf of California - in juxtaposition with the main cluster of similar intrusives in Sonora. Reconstruction also brings the Tertiary continental deposits of northern Baja in juxtaposition with the north-south trending belt of Tertiary continental deposits of Sonora, Mexico.

2. We utilized ERTS-1 imagery to check the validity of the existence of major trans-Baja fault zones. In the northern half of Baja which was not submerged during the Tertiary, several trans-Baja faults were verified. In southern Baja we observed discontinuous remnants of possible transverse breaks. It is suggested that the old transverse faults are marked by Tertiary and Quaternary volcanic cover and by a blanket of marine sediments of late Tertiary age.

3. ERTS-imagery shows that high albedo sediments similar to known late Tertiary marine sediments are widespread in southern and middle Baja and extend in places to the eastern side of the Peninsula. If our assumption that the high albedo areas are mostly marine sediments is verified by later field work, the distribution is highly significant. Implications are that much of the southern half of Baja was submerged during the late Tertiary and early Quaternary. It is envisioned that southern Baja at that time appeared as a train of islands in the Pacific.

4. ERTS-1 imagery was used to map major faults in northern Mexico and across the border in the United States. We found ample evidence that the Parras and parts of the Texas lineament are belts of major transverse shear faults in areas outside the supposed limit of the Texas and Parras

lineaments. We arrived at the conclusion that the entire southwestern part of North America was subject to large scale left-lateral segmatic shear. From the ages of the rocks most involved in the Parras shear it is evident that this major deformation took place contemporaneously with folding and thrusting of the Laramide orogeny. Late Tertiary rocks are much less affected. It is believed that the main phase of widespread left-lateral shear preceded the tensional rift faulting of the Basin and Range phase of tectonic development and was essentially older than the right lateral San Andreas type faulting.

A fundamental concept which may help explain many complexities in the tectonic development is beginning to emerge: The southwestern part of North America was torn by massive left-lateral shear of transverse trend (east-west) during the compressive stage of the late Mesozoic and early Cenozoic. This tectonic style has changed into tensional rifting (Basin and Range) and right-lateral shear later in the Cenozoic and Quaternary.

SCOPE AND OBJECTIVE:

In this period ERTS-1 imagery was utilized to study geological structures of Baja California and selected areas in mainland Mexico. The main objectives were 1) determine whether ERTS imagery reveal unique structures on both sides of the Gulf of California which indicate major lateral displacement of Baja relative to the mainland of North America; 2) determine the validity of major trans-Baja fault zones and extensions of submarine faults suggested in some models of plate tectonics; 3) identify major shear zones related to the Parras and Texas structural trends in Mexico, southwestern United States; 4) correlate observed faults with the seismicity pattern; 5) identify new significant geological structures of scientific interest which may suggest future investigations.

ERTS COVERAGE USED:

The area covered in this study includes Baja California and the northern part of the Mexican mainland. ERTS-1 imagery used to analyze this area are:

<u>Gulf of California</u>

MSS 1070-17502	MSS 1029-17231	MSS 1045-17115
MSS 1052-17495	MSS 1028-17183	MSS 1062-17063
MSS 1069-17443	MSS 1068-17385	MSS 1079-17015
MSS 1068-17394	MSS 1067-17335	MSS 1079-17012
MSS 1068-17391	MSS 1067-17333	MSS 1078-16565
MSS 1067-17342	MSS 1066-17281	MSS 1078-16563
MSS 1049-17340	MSS 1029-17225	MSS 1078-16560

MSS 1030-17292	MSS 1028-17174	MSS 1078-16554
MSS 1048-17290	MSS 1028-17171	MSS 1077-16511
MSS 1030-17285	MSS 1027-17120	MSS 1080-17071
MSS 1066-17283	MSS 1068-17382	MSS 1032-17384
		MSS 1065-17222

Mexican Interior

MSS 1078-16542	MSS 1038-16321	MSS 1075-16380
MSS 1078-16533	MSS 1042-16541	MSS 1078-16540
MSS 1078-16551	MSS 1060-16550	MSS 1079-16592
MSS 1079-17003	MSS 1078-16545	MSS 1079-17001
MSS 1062-17045	MSS 1062-17051	MSS 1045-17110
MSS 1045-17104	MSS 1049-16364	MSS 1028-17162
MSS 1058-16433	MSS 1028-17160	MSS 1039-16370
MSS 1065-17213	MSS 1047-17220	MSS 1059-16492
MSS 1059-16483	MSS 1039-16373	MSS 1039-16375
MSS 1058-16431	MSS 1077-16490	

An index map of the significant study area is seen in Figure 1.

ACCOMPLISHMENTS:

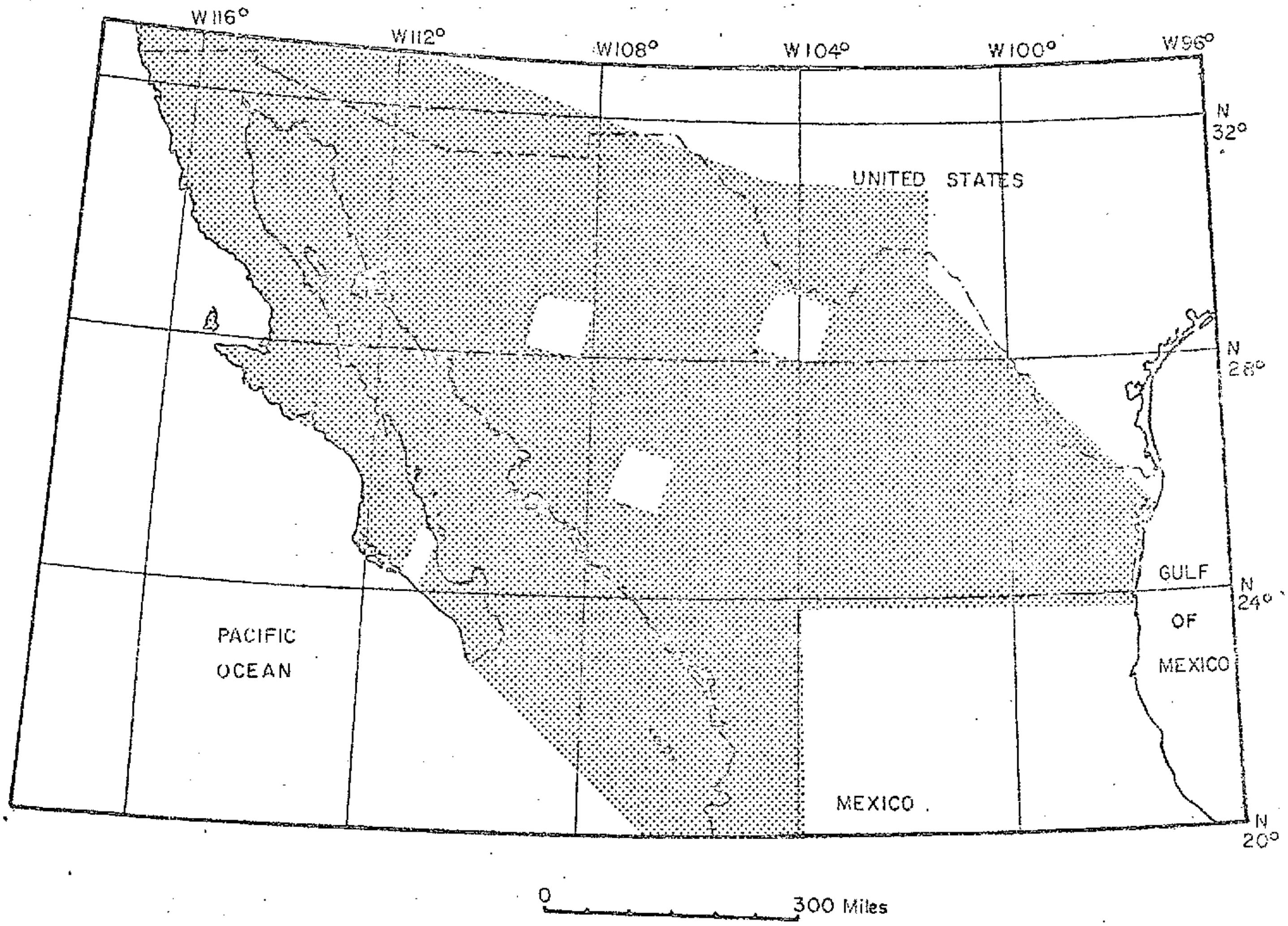
1. A black and white mosaic of the area bordering the Gulf of California was assembled using prints of band 5. The mosaic is uncontrolled and serves only to facilitate geological studies on a regional scale.

2. Overlays identifying key geographic reference features and geological structures relevant to the investigation were prepared.

3. Overlays showing the distribution and magnitude of historic earthquakes were prepared for each scene.

4. Geologic data on fault zones inferred from ERTS-1 imagery were plotted on overlays and correlated with previously known data. A total of 50 scenes were used to derive essential data on the fault pattern.

5. The new data derived from ERTS was analyzed in relation to pertinent facts in the literature and geological maps.



Area studied in the investigation.

FIGURE 1. INDEX MAP

SIGNIFICANT RESULTS:

1. Correlation Across Gulf of California (Ref: ERTS-1 # MSS 1049-17340, MSS 1029-17225, and MSS 1066-17281)

A strong geologic similarity between Isla Tiburon, Isla Angel de la Guarda in the Gulf of California and the San Carlos Range in mainland Mexico was observed.

The Tertiary volcanic rocks which cover those areas show a distinctive north trending grain or rill-like texture. This geomorphologic characteristic is probably due to intrinsic structural similarities and the volcanic rocks enhanced by similar conditions of erosion.

Throughout the entire length of Baja and the eastern side of the Gulf of California, this particular rill texture appears to be unique to the three areas (Fig. 2). The remarkable similarity of the terrain suggests that the three blocks were once adjacent. Isla Tiburon, however, appears to be locked in its present position with the Mexican mainland so Isla Angel de la Guarda seems to be the only large island that has moved. The block now forming the island of Isla Angel de la Guarda within the Gulf was probably situated somewhere to the southeast as part of the Mexican Mainland near latitude 28°N.

Assuming that Baja California has moved northwestward relative to the mainland the ERTS data were used to reconstruct a working model showing the initial position of the blocks prior to the displacement (Fig. 3).

It is significant to note that the reconstruction brings the prominent north-south trending fault belt of middle Baja (A, Fig. 3) in continuity with an equally prominent fault belt in Sonora, Mexico.

We have also plotted in Figure 3 the distribution of the early Cenozoic intrusives and the Tertiary continental deposits from the Geological Map of Mexico (Cserna, 1961). Our reconstruction model brings the isolated mass of early Cenozoic intrusive rocks now on the eastern side of Laguna Salada (Baja block) in juxtaposition with the main bulk of similar intrusives in Sonora. Tertiary Continental sediments form a north-south trending belt in Sonora. Similar reconstruction brings this belt in a position suggesting a continuation with similar exposures in Isla Angel de la Guarda and within Baja (Figure 3).

2. Identification and Verification of Major Faults in Baja California

Several major faults have been known in Baja California. Other faults and lineaments have been conjectured.

The occurrence and nature of transverse faults across Baja, particularly any strike-slip breaks, are of critical importance in tectonic models. One model considers that in the process of separation and displacement Baja California may have undergone some telescoping. Depending upon the model

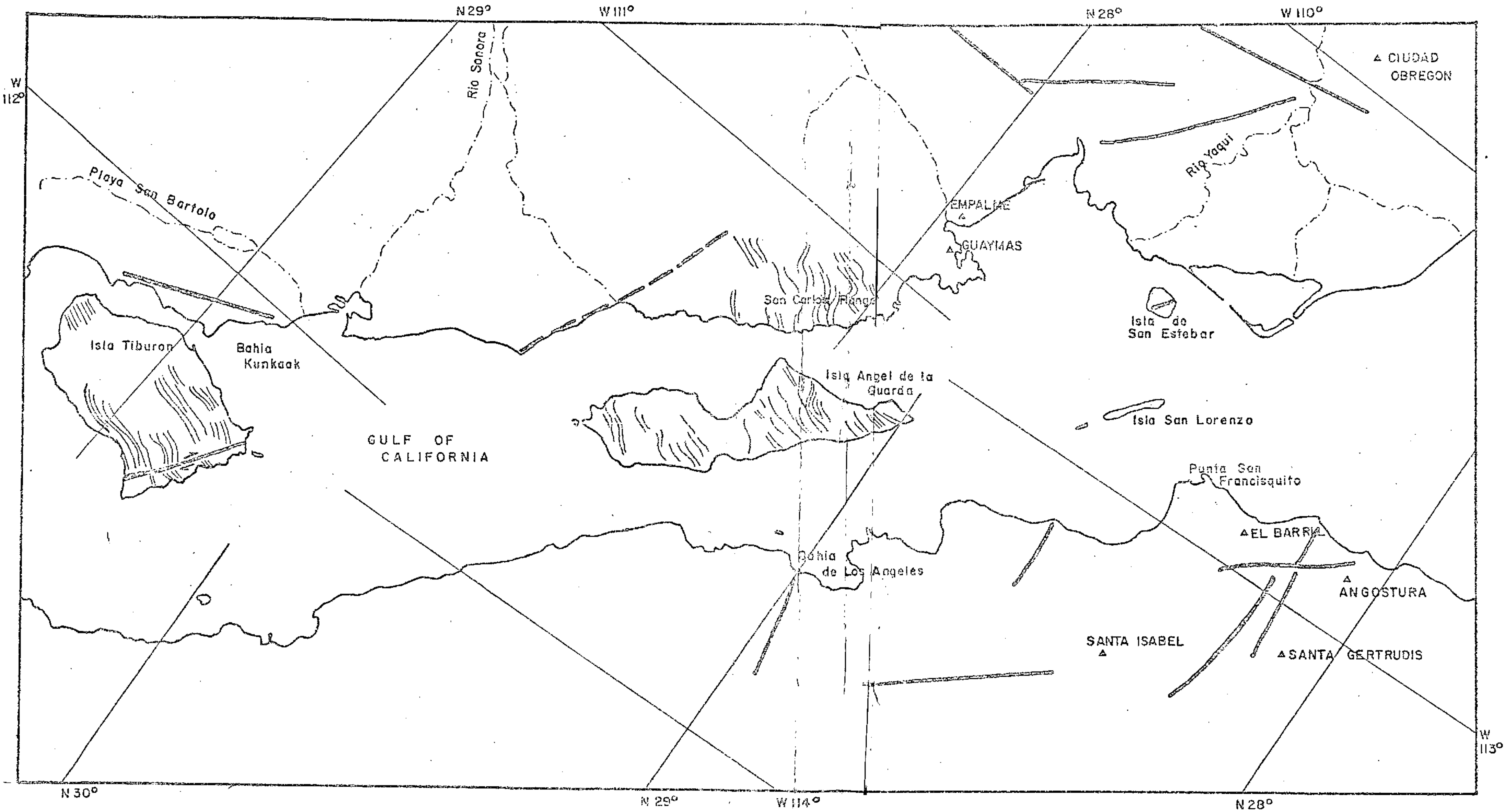


FIGURE 2. Reconstruction Model Showing Similarity of Rill Texture Between Isla Angel de la Guarda and the San Carlos Range. (The offset of Baja and Isla Angel de la Guarda is about 230 Km. SE of their present positions.)

Legend

- Town
- Drainage
- ERTS inferred fault or lineament
- Trendlines (rill texture)

FOLDOUT FRAME 1

FOLDOUT FRAME 2

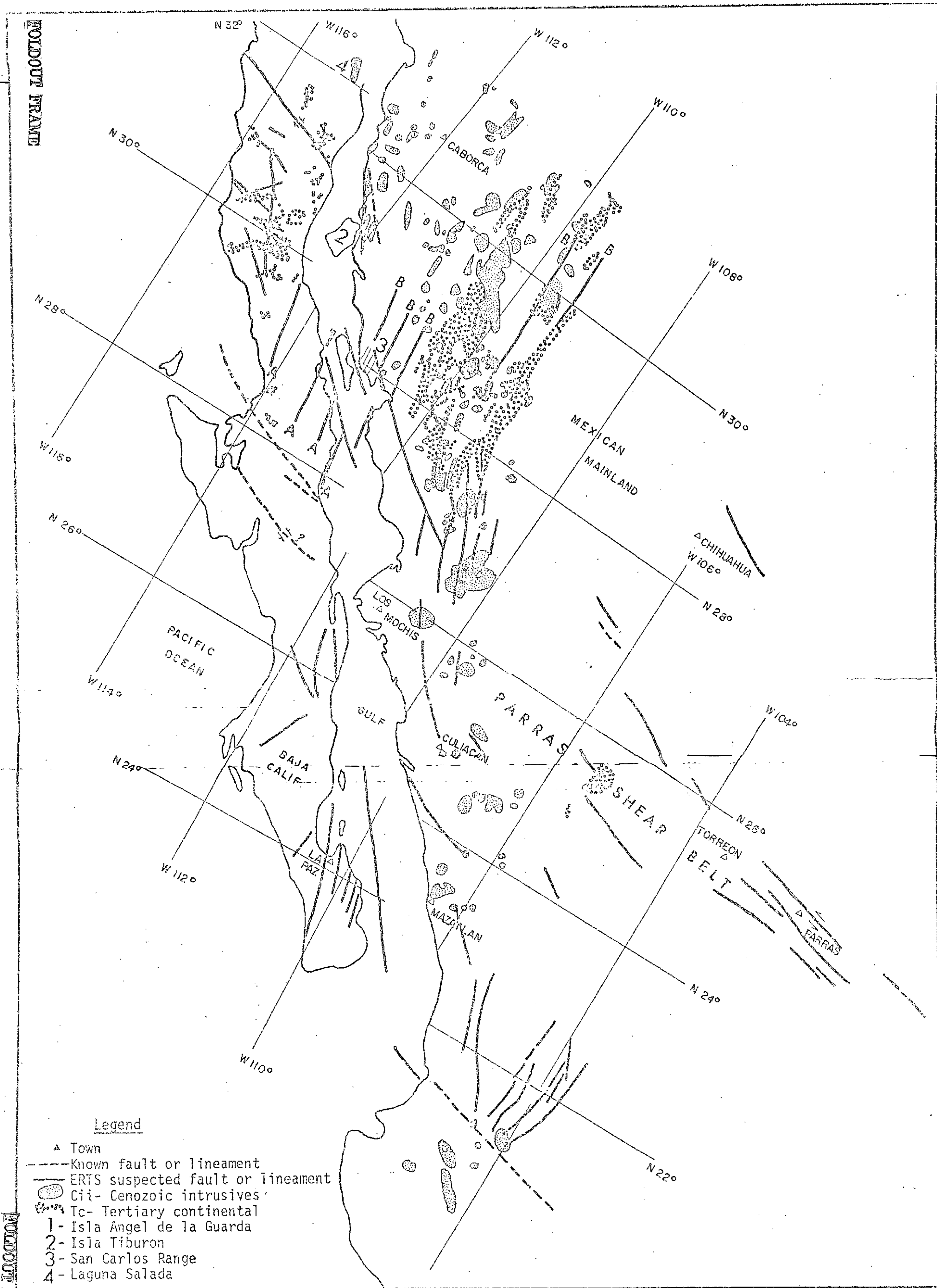
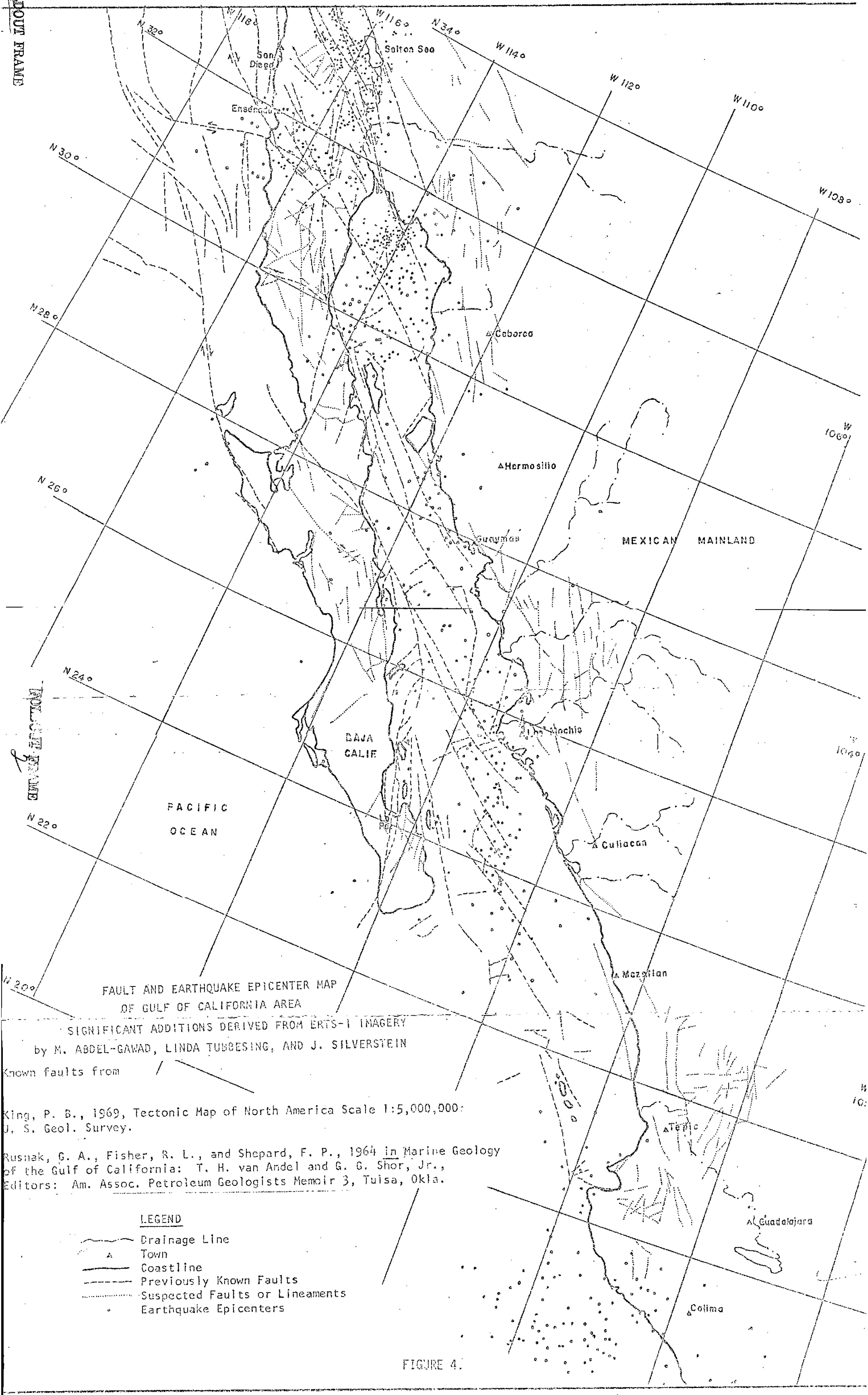


FIGURE 3. Reconstruction Model of Baja California and the Gulf Islands.



FAULT AND EARTHQUAKE EPICENTER MAP
OF GULF OF CALIFORNIA AREA

SIGNIFICANT ADDITIONS DERIVED FROM ERTS-1 IMAGERY

by M. ABDEL-GAWAD, LINDA TUBBESING, AND J. SILVERSTEIN

Known faults from

King, P. B., 1969, Tectonic Map of North America Scale 1:5,000,000: U. S. Geol. Survey.

Rusnak, G. A., Fisher, R. L., and Shepard, F. P., 1964 in Marine Geology of the Gulf of California: T. H. van Andel and G. G. Shor, Jr., Editors: Am. Assoc. Petroleum Geologists Memoir 3, Tulsa, Okla.

FIGURE 4.

and the sense of movement on trans-Baja faults telescoping could have resulted in considerable stretching of the Peninsula or its shortening. Displacement of Baja as one rigid block without significant telescoping has also been suggested. This underlies the importance of identifying major trans-Baja faults and their relation to faults within the Gulf and in mainland Mexico.

In Figure 4 we plotted the major faults in Baja differentiating the following classes:

Major known faults or lineaments proposed or conjectured in the literature
Faults or lineaments inferred in our ERTS investigation

A discussion of significant details follows:

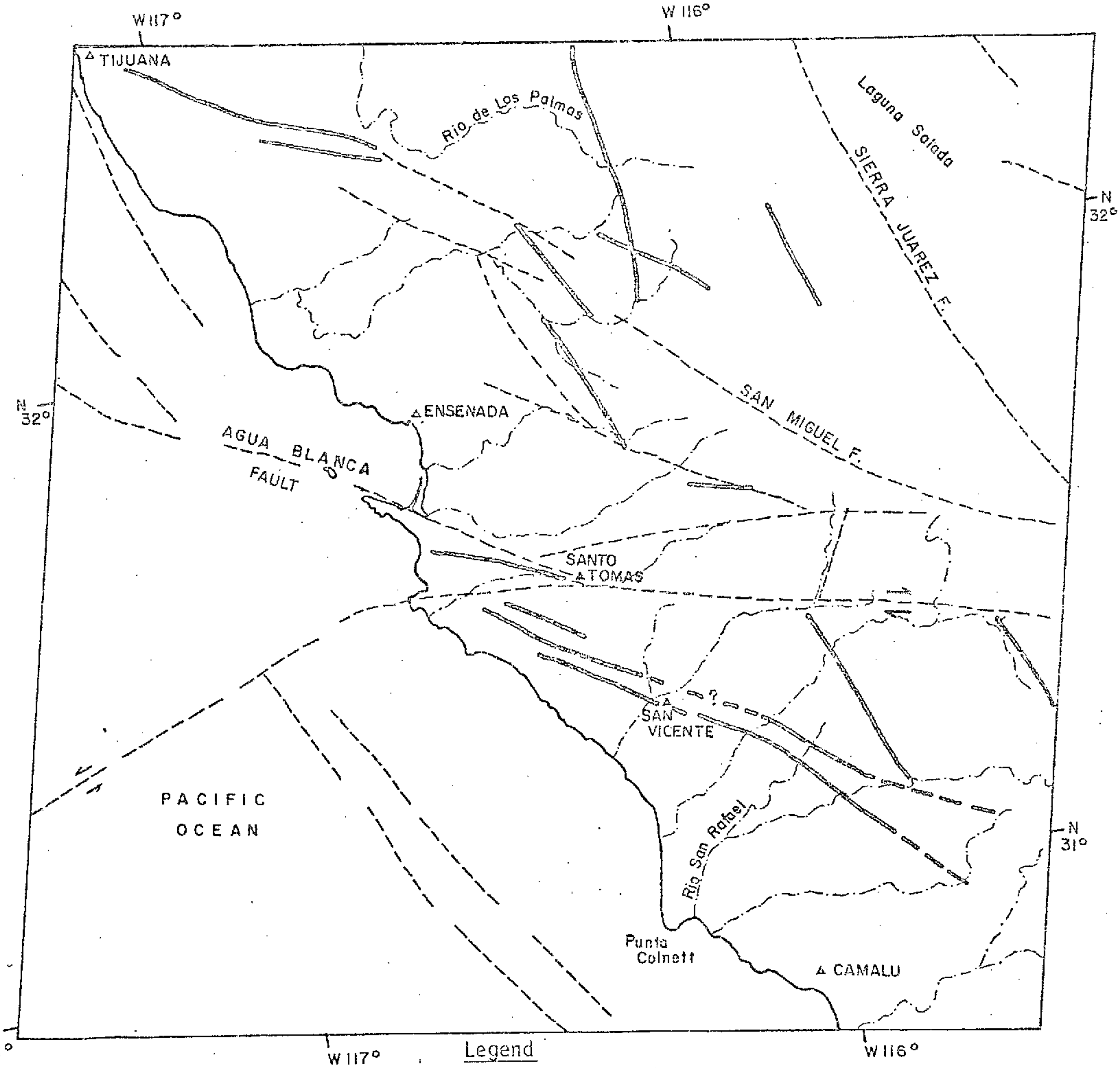
NORTHERN BAJA: In northern Baja which was not covered by ocean water since the Mesozoic, several transverse shear zones similar to Agua Blanca were identified in areas not covered by volcanic rocks. Faults previously known or conjectured were verified or questioned.

MSS 1052-17502: This ERTS image covers an area from Tijuana, Mexico, south past Ensenada to Punta Colnett (Fig. 5). In this part of Baja major transverse faults cutting across Baja are evident. The Agua Blanca fault is clearly visible in the ERTS imagery as it boldly cuts through several mountain ranges. An ERTS inferred transverse fault is observed south of the Agua Blanca fault 20 to 30 km in a NW direction. This fault zone meets the Agua Blanca fault near San Tomas. A possible right lateral movement is observed in this zone.

The Sierra Juarez fault zone is inferred by the structure of the mountains and basin area trending in a NNW direction. Although it is not as prominent as the Agua Blanca fault, its presence is seen.

The San Miguel fault, also recognizable in the ERTS photo, was mapped by Rusnak, Fisher, and Shepard, 1964. It extends northwestward into a fault zone recognized by King (1969). ERTS image 1052-17502 suggests that the fault zone extends across Baja to the Pacific, passing near Tijuana, Mexico. This Tijuana-San Miguel fault zone is a major one and is characterized by major earthquakes. In continuity and physiographic expression, this fault is not consistent. It is bold and clearly recognizable in places, but vague in others. This characteristic and the seismicity suggests that it is a major break which has not yet fully developed as a throughgoing fault. Seismic activity (as seen in Fig. 4) is mainly concentrated in the block north of the Agua Blanca fault. Although large earthquakes have occurred near large faults, mostly trending NW-SE, the earthquake pattern at large appears to trend NE-SW. Large shocks occur near the boundaries of the block (i.e. near faults). Tijuana, Ensenada, and San Tomas, Mexico lie in highly

MSS 1052-17502 Significant Faults in Northern Baja



Legend

- Town
- Drainage
- Known fault or lineament
- ERTS suspected fault of lineament

FIGURE 5.

seismic zones, being on projections of major active faults. Earthquakes seem to be unrelated to major physiographic features except faults.

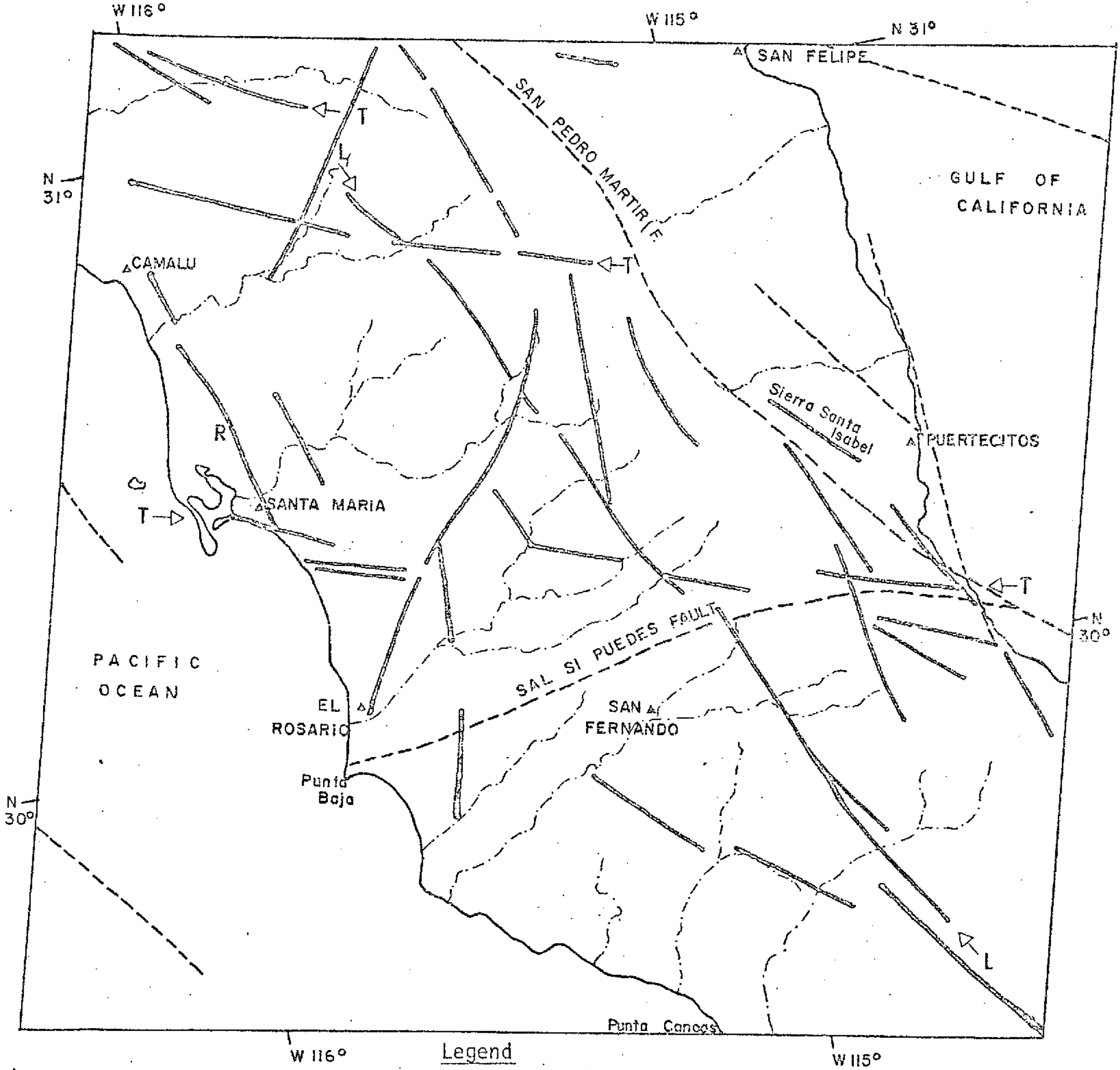
MSS 1069-17450: The area covered by this ERTS photo includes the area south of the Agua Blanca fault, including the Santo Domingo River, Santa Maria, El Rosario, and Punta Canoas (Fig. 6). This scene does not show evidence for any transverse fault cutting across the entire width of Baja. There is evidence against the existence of Sal Si Puedes fault suggested by Rusnak et al. (1964, plates 2 and 3). There are several other ERTS inferred faults, lineaments, and geological structures crossing perpendicular to the Sal Si Puedes fault that would seem to question its existence. Its surface expression is not clearly visible in the ERTS imagery. The San Pedro Martir fault trending NW is vaguely visible as it controls the long valley between the two ranges, Sierra San Pedro and Sierra Santa Isabel. There are several discontinuous transverse lineaments trending west-north-west; one extends from the area of Isla Miramar to Santa Maria (T). We also recognized: a major lineament trending northwest, running approximately along the axis of Baja and parallel to the San Pedro Martir fault (L); a probably, young fault (R) running parallel to the western coast just north of Santa Maria; and several other faults trending north and northeast.

The significant observation here is that the transverse faults show little or no displacement which is an essential criteria if telescoping of Baja has taken place. The knee shape of Baja here does not appear to be fault influenced.

SOUTHERN BAJA: In southern Baja only segments of transverse faults are observed. It is suggested that late Tertiary and Quaternary volcanism and the submergence of the southern half of Baja have acted to cover large segments of major trans-Baja faults. The discovery of several segments of trans-Baja faults supports the concept that Baja was broken into several major blocks which moved differentially as a result of the spreading of the Gulf of California.

MSS 1067-17342: This ERTS image covers the areas of Ojo de Liebre, Punta Abreojos, San Ignacio, Santa Rosalia, and Bahia San Carlos (Fig. 7). Previously known faults or conjectured faults in this area include the Santa Rosalia fault which, for instance, shows no surface expression in ERTS as it extends through the alluvium SW of the mountains. In this area, near Santo Domingo, ERTS inferred lineaments run obliquely in a NNW direction to the Santa Rosalia fault. The eastern half of the fault runs through the mountains west of Bahia San Carlos. Although the actual fault trace is extremely vague several other ERTS inferred lineaments close by trend in the same direction, parallel to the known fault and are clearly seen. There are also other lineaments trending EW and NE. The San Benito-Cedros-Tortuga fault is also very poor in surface expression. Trending NW, its path runs just south of the Sierra Placeres, and then extends into the valley alluvium. Its existence is not verified by ERTS imagery anywhere along its conjectured path. Oblique to its position several other ERTS lineaments trend NNE, but mostly

MSS 1069-17450 Significant Faults in Northern Baja



Legend

Town

Drainage

Known fault or lineament

ERTS suspected fault of lineament

FIGURE 6.

MSS 1067-17342 Significant Faults in Southern Baja

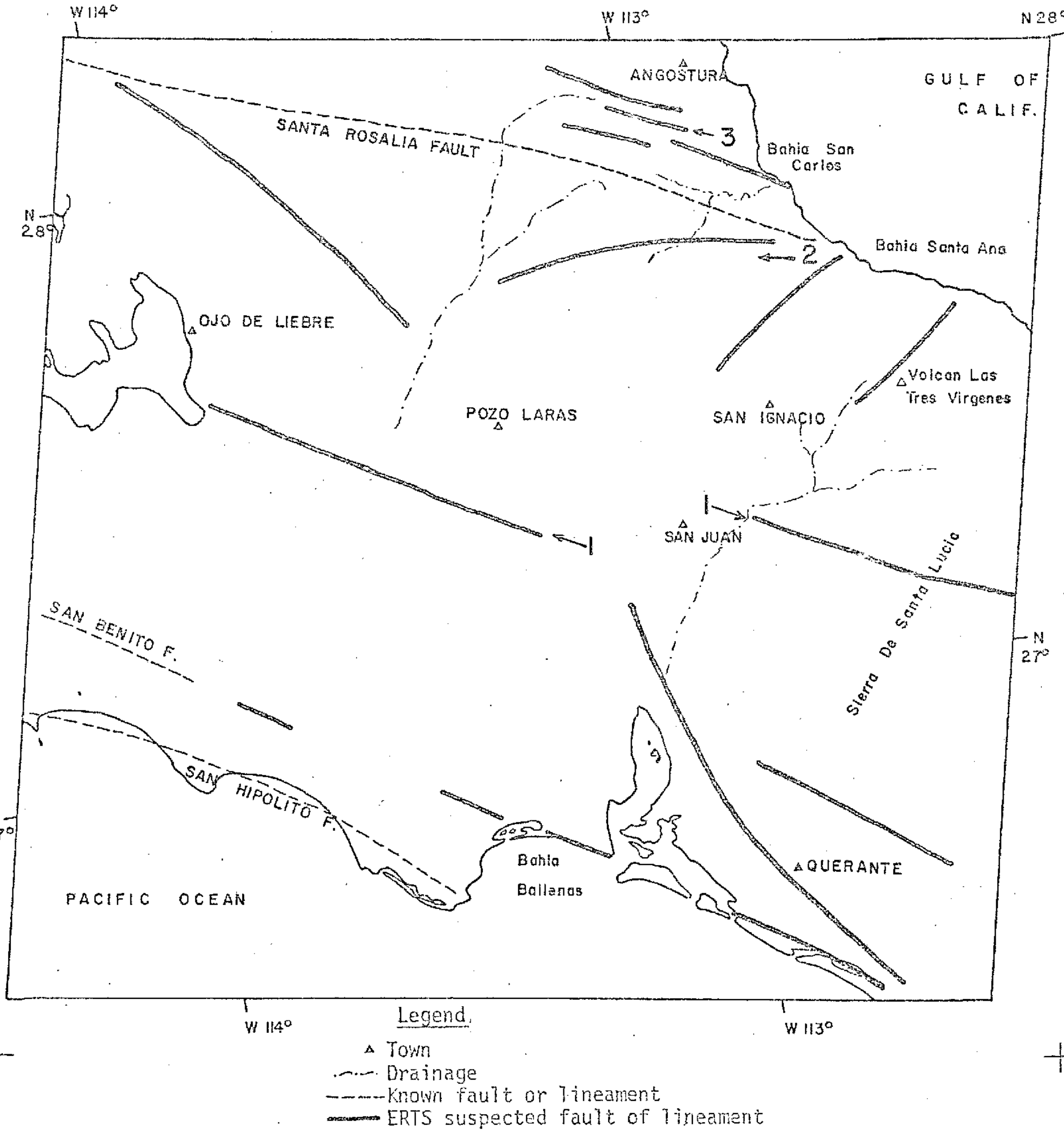


FIGURE 7.

NNW through the Sierra Placeres. The San Hipolito fault is mainly an offshore fault crossing the land only twice. In both these areas, Quaternary alluvium is found, which suggests why the fault cannot be clearly seen. Even though the fault may be covered up by this alluvium, there appears to be similar NW trending lineaments in the area.

Several ERTS inferred Northwest trending lineaments can be seen in this photo. One extends from Ojo de Liebre to San Juan, and another goes through the range Sierra de Santa Lucia, south of Santa Rosalia (1). North of the Santa Rosalia fault, several other northwest lineaments cross the mountains just west of the Bahia San Carlos (3). Near the Gulf, where the Santa Rosalia fault extends into the Bahia Santa Ana, a westward trending lineament intersects the Santa Rosalia fault and extends into the Coastal ranges (2). There is also a possible extension of the San Benito F. down past Bahia Ballenas. The transverse faults in this ERTS photo are pre-Quaternary masked by Quaternary volcanics, Pleistocene marine sediments, and alluvium.

MSS 1028-17290: The towns of Santa Rosalia, La Purisima, and Conejo are included in this ERTS photo. This part of Baja is made up of Tertiary and Quaternary volcanics. Faults are trending NW, but none appear to be recently active. Several lineaments are observed, generally parallel to the peninsula. If they are faults, they are either old, covered by volcanics, or have not moved for some time. The area generally gives the impression of stability except for the abundance of very well defined recent volcanics. No transverse faults of unquestionable nature are observed.

MSS 1028-17180 and MSS 1028-17183: These two ERTS-1 photos cover the southernmost tip of Baja from La Paz south to the tip (Fig. 8). Most of the major faults have been mapped, but a few additional faults are inferred from the imagery. The only major fault in this area that extends onto the land is the La Paz fault that trends approximately NNW. It is clearly visible in the ERTS image 1028-17180 and can also be inferred in 1028-17183. ERTS imagery suggests a possible left lateral movement on the fault. Another lineament or fault can be seen just west of the La Paz fault about 5 km. It also trends NW with a possible left lateral movement. Viewing Figs. 8 and 4 the significant observations are:

1. Many of the N-S trending faults show evidence of recent activity. Yet the record of historic earthquakes on the land area can be misleading. From the geologic record the entire southern part of Baja California is susceptible to major shocks and recurrence of fault movement. It is evident from the disruption of drainage lines and fault traces cutting the alluvium and particularly the extent of headward erosion of streams flowing west from the eastward tilted Santa de S. Lazaro block. This indicates the recency of fault breakage and tilt, but yet historic earthquakes are almost void in this land area.

2. The earthquakes form a belt trending north within the Gulf of California significantly oblique to the major suboceanic faults which trend NW.

MSS 1028-17180 and MSS 1028-17183 Faults and Seismic Activity of Southern Baja

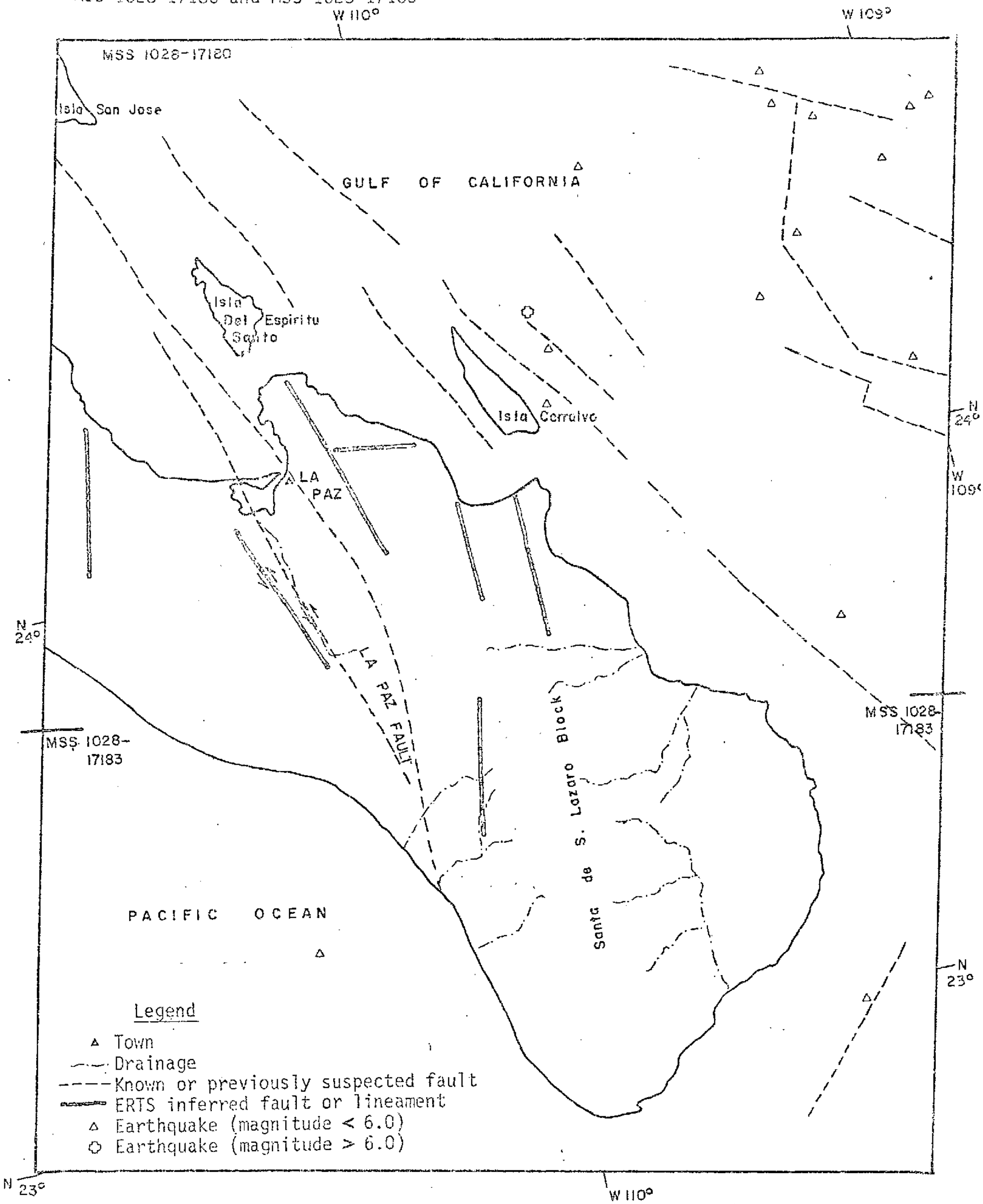


FIGURE 8.

3. The distribution of major earthquakes (greater than 6.0 magnitude) show alignments along two definite lines. The first trends N-S from Isla Cerralvo towards Topolobampo on the Mexican mainland. The second line trends N-W approximately aligned with a major suboceanic fault.

4. In the southern part of Baja the N-S fault pattern is decidedly different from the northwest trend of suboceanic faults. The latter do not appear to extend into the land mass of Baja.

MSS 1029-17231: This ERTS picture of the Baja coast near Tripui shows an interesting fault and quake comparison. A seismic zone occurs east of Isla de Carmen (Fig. 4). The major quakes are lined up along a NW trend within the gulf while the lesser earthquakes cluster in a NE trend. Most of the earthquakes occur NE of the faults, known or inferred, under the Gulf.

SEISMICITY:

After earthquakes were plotted for each ERTS photo, a large mosaic was made and a seismicity pattern appeared (Fig. 4). From the Gulf head down to the Pacific Ocean west of Colima, the heaviest earthquake activity occurs in the Gulf of California. Northwestward from the Gulf head the earthquakes occur inland, forming a large cluster from Ensenada to the Salton Sea. South of the Agua Blanca fault, Baja California has very minimal seismic activity. This is also the case with the NW Mexican mainland. Four main areas appear to be clustered with earthquakes.

1. Inland, between the Agua Blanca fault zone and the Salton Sea area.

2. In the Gulf, west of Caborca, between latitude N30° and N32°.

3. In the Gulf between latitude N24° and N28°, but heaviest between N24° and N26°.

4. West of Colima in the Pacific Ocean.

TRANSVERSE FAULTS AND SHEAR ZONES IN NORTHERN MEXICO

A major system of transverse faults related to the Texas and Parras lineaments has been recognized. We mapped outstanding strands of this system within an extensive area north of 24°N in Mexico and across the international U.S.-Mexico border (Figure 9).

The most outstanding element of this system is a left-lateral shear zone trending N70°W extending from south of Monterrey, Mexico through Saltillo, Parras, Torreon, and Parral.

The existence of the "Parras Lineament" has been suggested in the literature (e.g. Schmitt, 1966). Our work confirms that this lineament is a major transverse structural discontinuity and further defines the Parras lineament as an outstanding crustal break characterized by left-lateral shear.

Within the area lying between the Texas and Parras lineaments, we found important fault strands of similar transverse trend. The fault pattern strongly indicates that the entire southern part of the North American continent has been subject to an enormous shear couple of sub-continental proportions.

Correlation of geological maps with our fault map made it abundantly clear that the shearing deformation has taken place contemporaneously with folding in the Sierra Madre Oriental of Mexico and represents therefore an important tectonic element of the Laramide "Orogeny."

It is clear from comparing Figures 9 & 10 that the Cretaceous belt of sedimentary rocks in the Sierra Madre Oriental is profoundly affected by shearing deformation as well as folding. The post-orogenic Eocene marine molasse (Claiborne group) of the Gulf of Mexico appears to be less affected, while the Gulf Coast Miocene, Pliocene, and Quaternary sedimentary rocks show little evidence of deformation although some lineaments of transverse trend could still be detected.

Within the Cenozoic volcanic province of the Sierra Madre Occidental the shearing deformation of the Parras zone is not readily evident although important transverse lineaments are observed in places.

Evidently the shear belt lies buried beneath the immense volcanic cover of the Sierra Madre Occidental and any early Tertiary fault strands have been largely obliterated by the late Tertiary uplift, the development of Gulf of California system of faults, and the great system of canyons which drain the range.

If we consider the reconstructed position of Baja (Figure 3) in this context, it appears very likely that the great Transverse fault zones of Baja may represent old scars of the Mexican shear system, rejuvenated in places (e.g. Agua Blanca fault) by later Tertiary and Quaternary tectonic movements which brought about the development of the Gulf of California and the displacement of Baja.

A proposed tectonic model illustrating the effect of Texas and Parras shears on major orogenic belts is shown in Figure 11. Of particular significance is the position of the Millard Belt described by Kay (1951). This Paleozoic miogeosynclinal sedimentary belt is exposed in southern and eastern Nevada and western Utah. The southern end abruptly ends in southeastern California. The southern extension of the Millard belt had remained beyond the Texas shear which has remained an enigma for a long time until the remarkable similarity of the

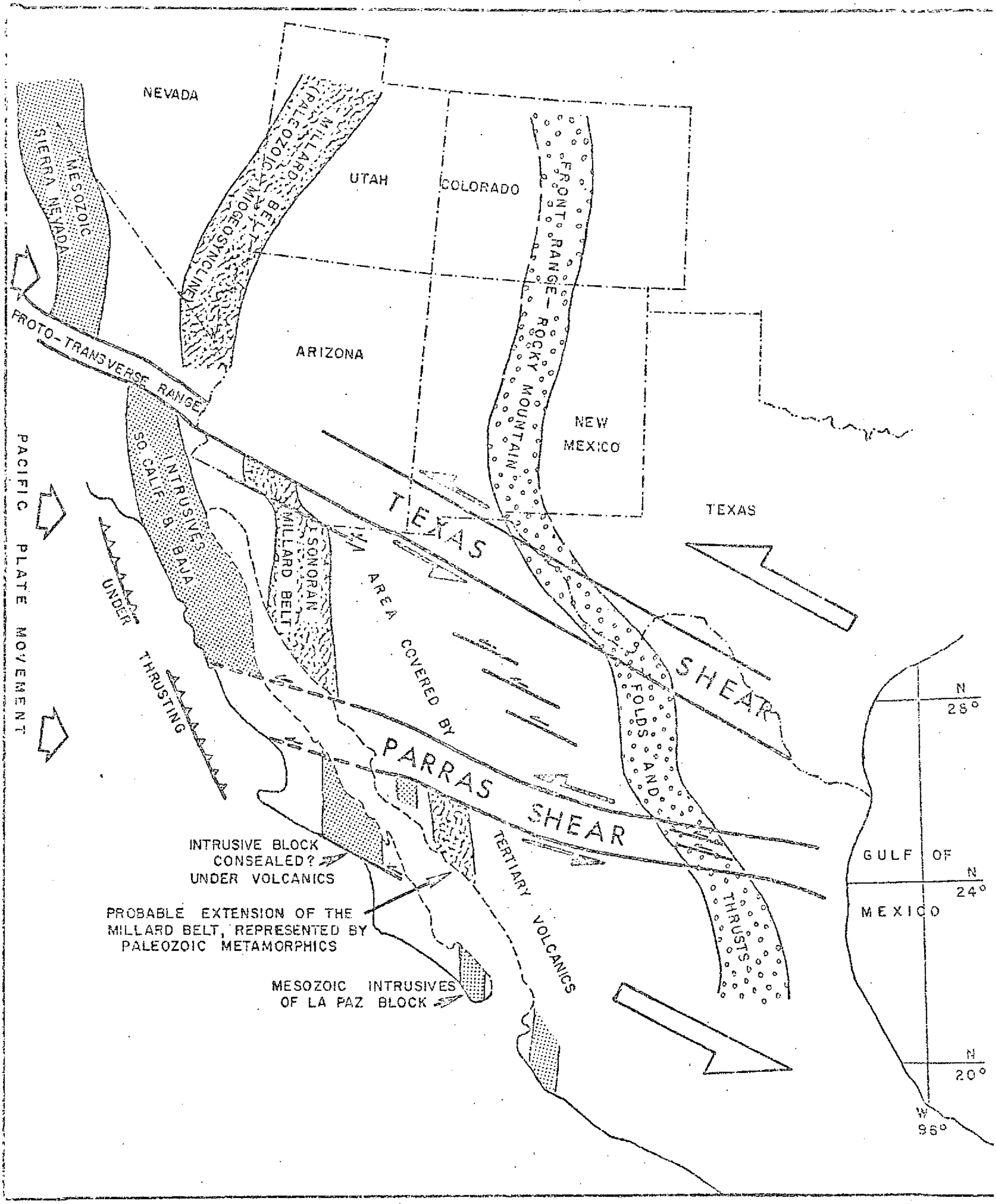


FIGURE 11. Tectonic Model Showing Effect of Parras and Texas Shears on Major Orogenic Belts Prior to Basin and Range Fragmentation

Paleozoic rocks exposed in western Sonora, Mexico was pointed out by King (1969). The position of the two segments of the Millard Belt leaves very little doubt that the Texas lineament coincides with a major sinistral shear.

We reason that the left-handed Parras shear has probably caused a second major offset of the Millard Belt. The offset extension most likely occurs in the vicinity of Culiacan, Mexico. Indeed the Geological Map of Mexico shows a relatively small exposure of Paleozoic metamorphic rocks along Rio San Lorenzo (near Long. W106°45' Lat. N24°40'). Since the area is now largely covered by the Sierra Madre Occidental volcanic rocks, the older Paleozoic rocks would crop out only in erosional windows.

Left-Lateral Shear Features Along Parras Belt

We have selected three examples within the folded Sierra Madre Oriental and the Plateau Central to show the effect of the Parras shear and structures indicating its left-lateral nature.

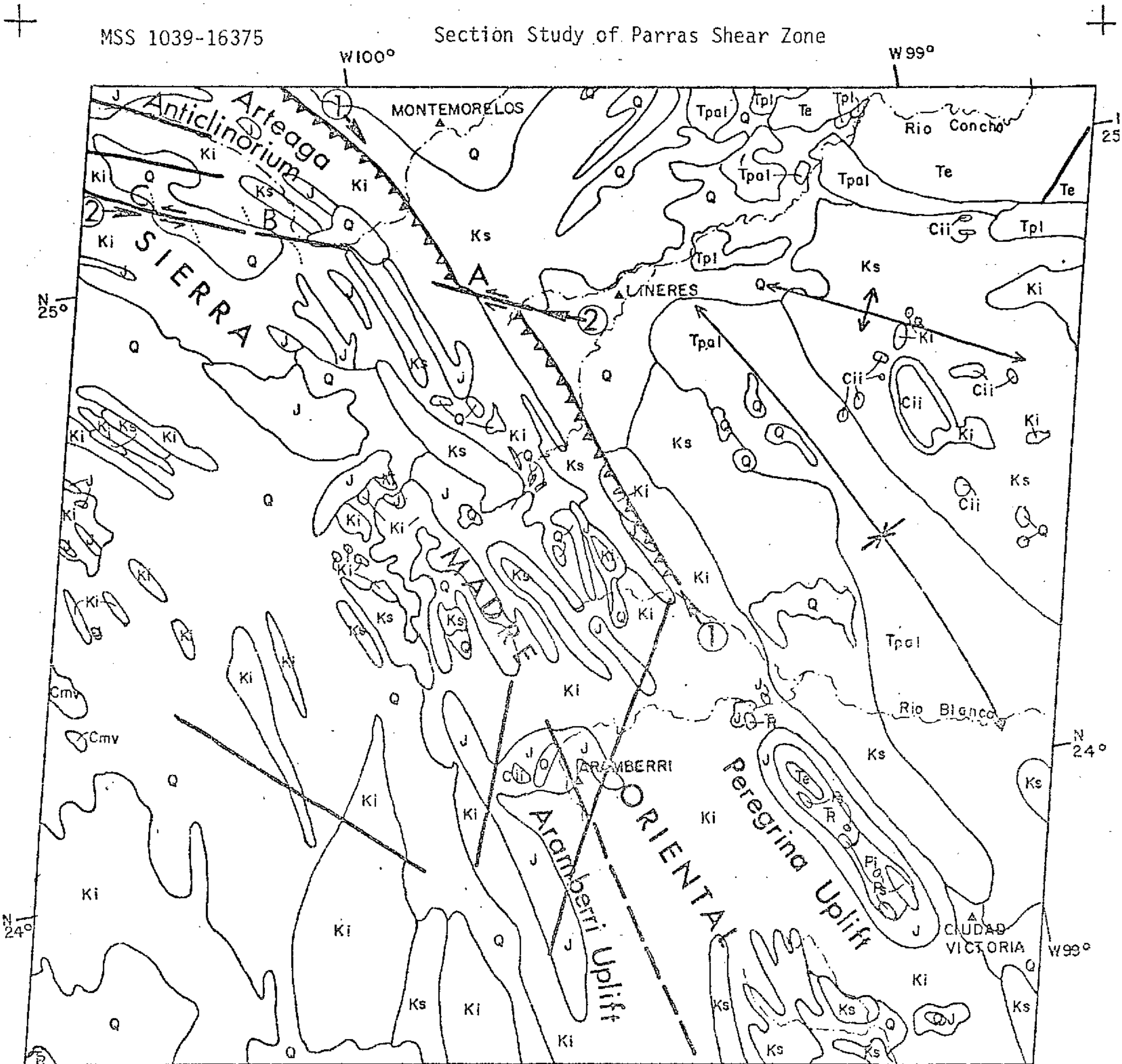
Figure 12 (MSS 1039-16375) shows the Sierra Madre Oriental with its complexly folded Mesozoic marine sedimentary rocks. The three systems of faults discernible here trend north-northwest, northeast, and west-northwest.

The eastern front of the range, Fault 1-1, is a thrust shown in part in the Tectonic Map of North America (King, 1969) and discussed elsewhere by Kellum (1930).

The transverse fault (2-2, Fig. A) quite clearly displaces the eastern front of the Range and the thrust fault approximately 10 km near point A. Farther northwest at points B and C similar displacements of the Lower Cretaceous, Upper Cretaceous, and Jurassic strata are observed. Between points A and B the continuity of the tear fault (2-2) is uncertain and is evidently due to the complex relationship between thrust and wrench faulting. These types of faults often merge or change from recognizable breaks into flextures and tight folds.

Directly north (Fig. 13, MS1039-16373) of the Arteaga anticlinoram a major zone of transverse shearing is evident. The transverse lineaments 3 and 4 (Fig. 13) are associated with profound flextures in the structural contours and isopach lines (King 1969). Towards the east little or no surface expression of the lineaments is detected across the Tertiary formations (Tpal, Te, To, Tm) which indicates an active pre-Tertiary age. Farther west a great east-west trending structure discontinuity passes through the Parras Synclinorium (1, Fig. 14, MSS 1077-16490). The tightly folded Cretaceous strata forming the south rim of the Parras Syclinorium are cut by large strike faults trending east-west (2,3 Fig. 14). The regional orientation of the Los Alamitos uplift (anticline) axis and the two anticlines west of it trend oblique to the Parras Fault Zone at an angle consistent with left-lateral shear along the Parras belt. It is evident however that the Parras fault belt is not a single

MSS 1039-16375 Section Study of Parras Shear Zone



Legend

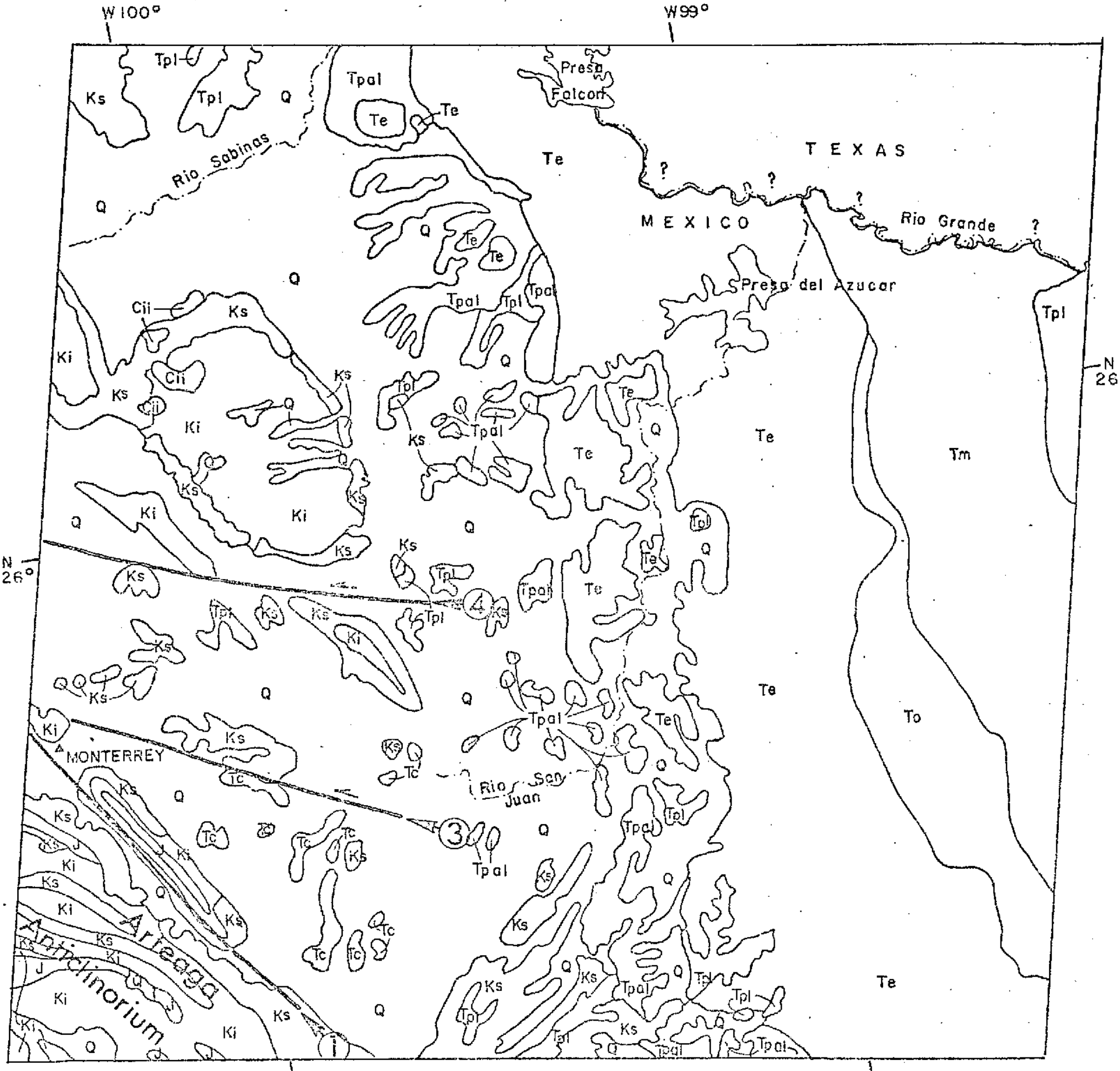
- Town
- Drainage
- ERTS inferred fault or lineament
- Known thrust fault
- Known anticline
- Known syncline
- Trendline of contacts

Geologic Boundaries:

Pi- Paleozoic inferior Te- Eocene
Ps- Paleozoic superior Tpal- Paleocene
Ks- Cretaceous superior Q- Quaternary
Ki- Cretaceous inferior Tpl- Pliocene
Cii- Cenozoic inferior, intrusives
J- Jurassic TR- Triassic

FIGURE 12.

MSS 1039-16373 Section Study of Parras Shear Zone



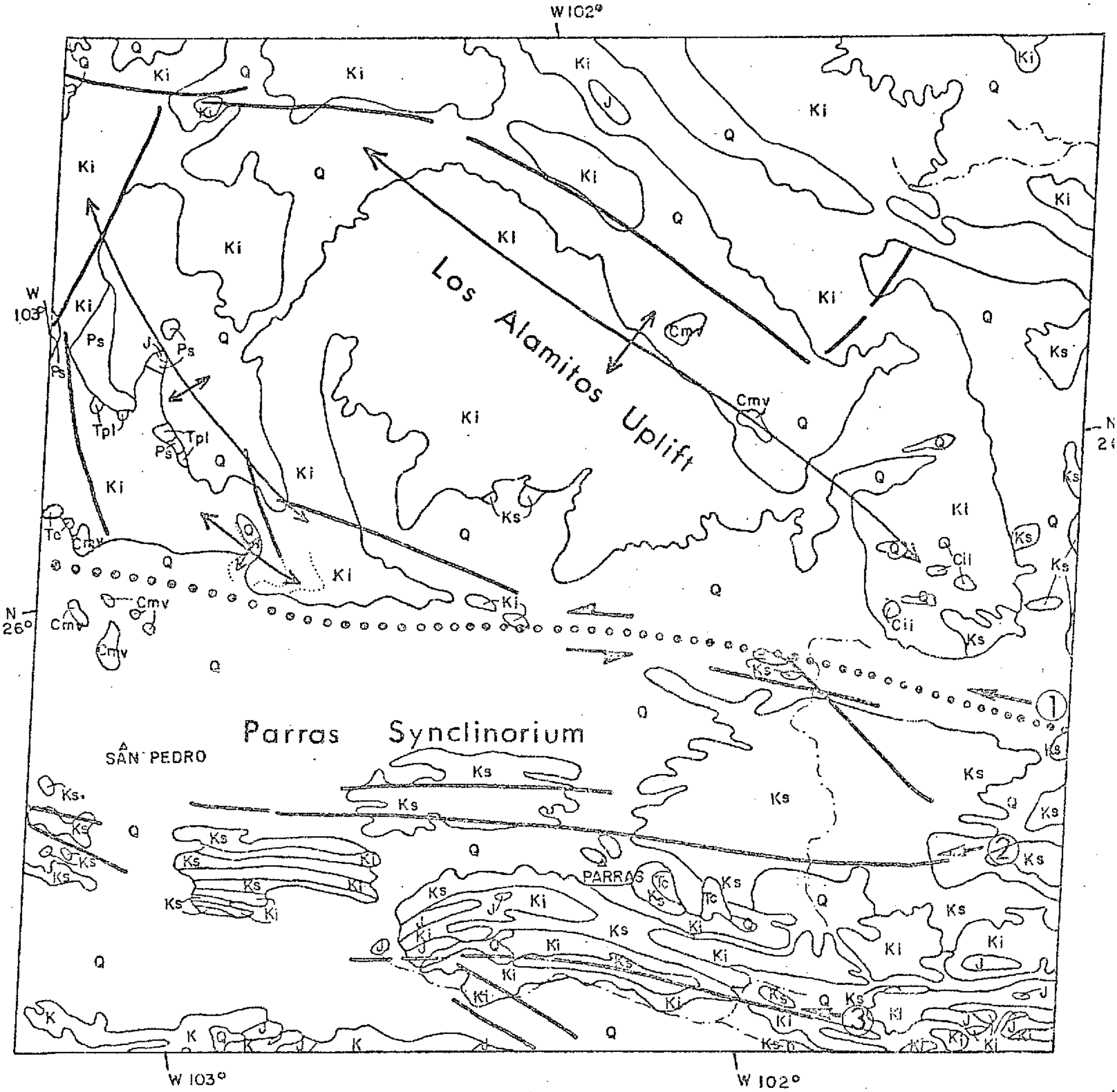
Legend

▲ Town
ERTS inferred fault or lineament
Drainage

Geologic Boundaries:
Ks- Cretaceous superior
Ki- Cretaceous inferior
Tm- Miocene
Te- Eocene
Tpal- Paleocene
Tc- Tertiary continental
Cii- Cenozoic inferior, intrusives
Q- Quaternary
Tpl- Pliocene
To- Oligocene
J- Jurassic

FIGURE 13.

MSS 1077-16490 Section Study of Parras Shear Zone



Legend

- Town
- Drainage
- Known fault or lineament
- Syncline
- Anticline
- Discontinuity
- ERTS inferred lineament or fault
- Trendlines of contacts

Geologic Boundaries:

Ks- Cretaceous superior
Ki- Cretaceous inferior
J- Jurassic
Ps- Paleozoic superior
Cmv- Middle Cenozoic volcanics
Cii- Cenozoic inferior, intrusives

Q- Quaternary
Tpl- Pliocene
Tc- Tertiary continen

FIGURE 14.

throughgoing surface break. It is rather a broad region where profound crustal breaks in depth are expressed in the sedimentary section above the form of regional flextures and tight folds passing in places into en echelon and discontinuous wrench faults and thrusts. We found from studying some 50 ERTS scenes that east-west and west-northwest trending breaks are pervasive in northern Mexico and across the border in the U.S. The breaks are particularly profound along the Parras and the Texas belts.

Projection of Parras Shear Across Sierra Madre Occidental

The Sierra Madre Occidental lies on the western side of Miuland, Mexico. This range is covered by an immense volume of volcanic rocks generally considered of middle Cenozoic age. The huge canyons which drain the range into the Gulf of California have deep gorges and rather youthful geomorphologic features attesting to the relatively recent uplift of the range.

We studied all ERTS-1 scenes of this range between latitudes 20° and 31°N in order to determine whether the range shows any features which could be related to the Parras or other transverse shear structures.

We found that the prevailing fracture pattern consists mainly of two systems: a northsouth and northwest-southeast, parallel to the Gulf of California. No major transverse breaks were identified with certainty. In places shown in Figure 3 there are some lineaments of transverse trend. There are generally observed in the eastern and western flanks of the range. It is evident however that if the Parras Shear ever affected that area, the evidence for its presence must lie in older rocks underneath the volcanic cover. We must assume therefore that the Parras Shear either terminated east of the Sierra Madre Oriental or more likely it has ceased to be an active feature since the middle Cenozoic volcanics were emplaced.

As mentioned earlier in our discussion of Baja, the reconstruction of the peninsula brings the trans-Baja faults in the middle part of the Peninsula in alignment with the westward projection of the Parras Shear. This apparent alignment may be merely coincidental, but may conceivably be an expression of the Parras belt continuity across the site of the Gulf prior to its inception.

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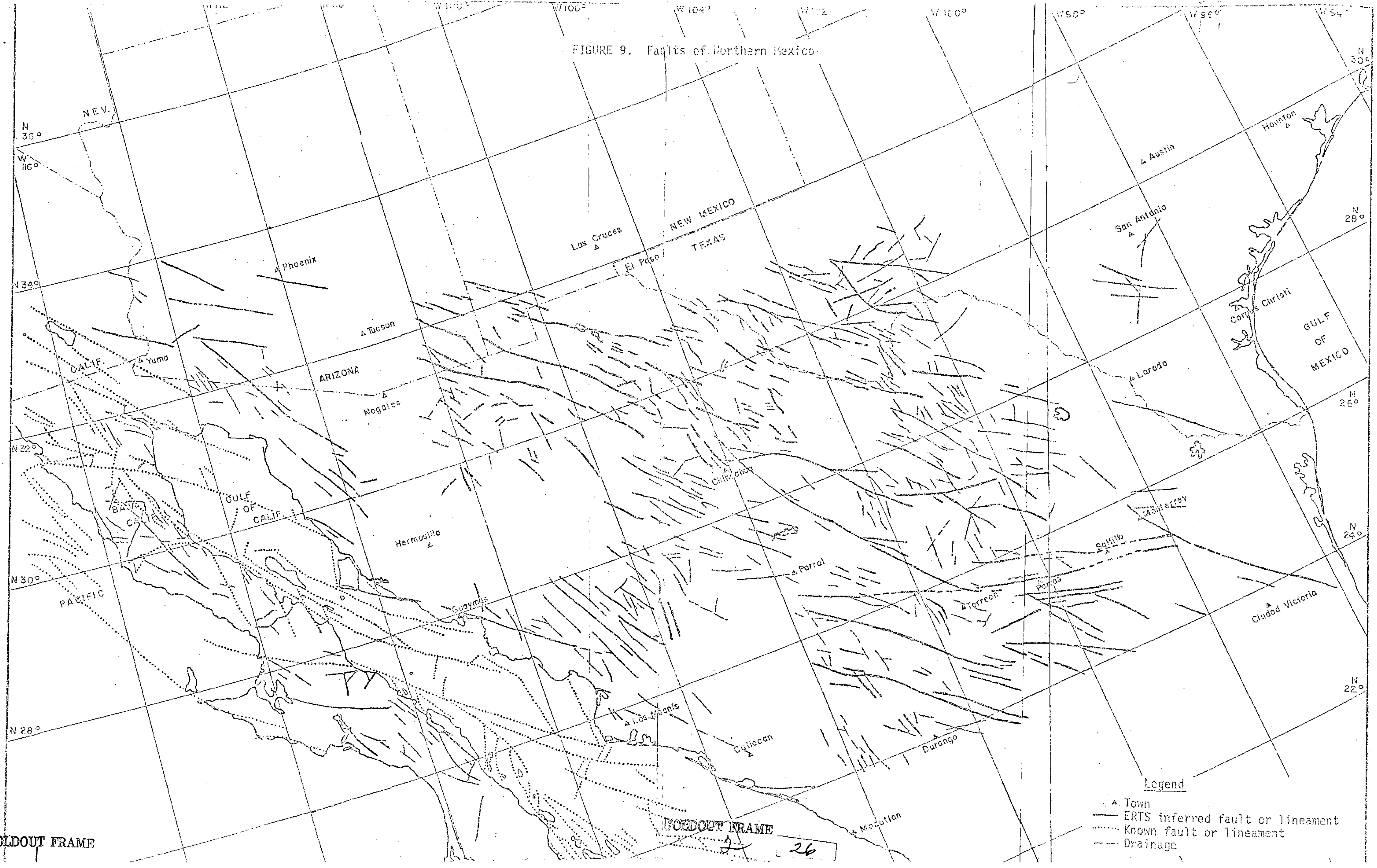
FIGURE 9. Faults of Northern Mexico



FOLDOUT FRAME

FOLDOUT FRAME 2

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